

Section 605. FURNISHING PORTLAND CEMENT CONCRETE (QUALITY ASSURANCE)

605.01 Description. Portland cement concrete covered by the Department's concrete quality assurance (QA) program will be accepted and paid for using the procedures described in this section.

The following quantities and/or types of concrete are not covered by this section but will be accepted and paid for according to the appropriate sections of these standard specifications.

Pavement patching mixtures designated for early open to traffic strengths
Structural concrete repair mixtures, and concrete patching mortar and grout
MDOT specified Concrete Grade HE except as described in subsection 605.03.C.2.
Prestressed concrete
Bridge deck overlay concrete mixtures including latex modified concrete
Smaller quantities of concrete and project-specific modified concrete mixtures
Grade X concrete

A. Terminology Used.

1. **Test Result.** An initial strength test result consists of the average 28-day compressive strength of two 6- by 12-inch cylinders. If either non-destructive testing or coring is required, a test result is one reading taken with an approved non-destructive test instrument or the compressive strength of one concrete core.
2. **Critical Concrete QA Items.** Concrete pay items which are subject to positive or negative pay adjustments based on 28-day compressive strength. Substructure concrete, superstructure concrete and concrete pavement items including shoulders and ramps are critical concrete QA pay items.
3. **Non-Critical Concrete QA Item.** Concrete pay items which are not eligible for positive pay adjustments, but are subject to negative pay adjustments, if applicable, based on 28-day compressive strength. Non-critical concrete QA items include, but are not limited to, curb and gutter, slope paving and sidewalks. Grade T concrete, concrete paving patching mixtures, silica fume modified concrete, and concrete mixtures containing ground granulated blast furnace slag and Type K cement are considered non-critical concrete QA items for the purpose of this acceptance program.
4. **Verification Strength.** The compressive strength that a concrete mix design must be shown capable of meeting prior to project production. Mix verification may be based on trial batches or by documentation from previous use of the mix as outlined in subsection 605.02.B.

605.02. Concrete QA Mix Design. It is the responsibility of the Contractor to provide concrete mix designs which will meet specified temperature, slump, air content, and compressive strength. If the Contractor proposes a mix design which exhibits temperature, slump or air content characteristics other than those specified in section 601, this variance must be requested in writing

at the time the mix design is submitted and the trial batch method of mix design verification must be used.

Mix design documentation must include sufficient information on constituent materials and admixtures along with compressive strength test results to allow the Engineer to fully evaluate the expected performance of the concrete mix. Contractor mix designs covered by the concrete QA program must meet the requirements of Table 605-1.

- A. **Mix Design Proportioning.** The designs shall be computed and set up in accordance with ACI Standard 211.1 as applicable. The mix design basis for bulk volume, dry loose or dry rodded method, of coarse aggregate per unit volume of concrete shall be between 65 and 75 percent, inclusive. Dry loose or dry rodded unit weight of coarse aggregate shall be determined in accordance with ASTM C 29 shoveling procedure or rodding procedure, respectively. The material shall be dried before testing.
- B. **Mix Design Documentation and Review.** The Contractor shall submit one or more mix designs for each grade of concrete required on the project to the Engineer for review. Mix designs, including all required documentation, shall be submitted 10 calendar days prior to the anticipated date of placement. Each mix design shall be numbered, or otherwise identified, and all accompanying documentation must be referenced to the appropriate mix design number. Each mix design shall also be referenced to the appropriate method of verification under which it is being submitted for review. Mix design submittals which do not include all required documentation will be considered incomplete and will be returned to the Contractor without review.

Specific information, as stated below, must accompany the mix designs to document that the concrete is capable of meeting the cement content, water/cement ratio and verification strength. All supporting mix design documentation, including test reports and mix proportion adjustment calculations, must be provided by and be traceable to a laboratory meeting the requirements of subsection 605.02.D.

Each proposed mix design shall be submitted on forms acceptable to the Department and must list the source of materials, specific gravity of constituents, aggregate absorption, dry weights, dry loose or dry rodded unit weight of coarse aggregate (whichever is used as the basis for design), aggregate correction factors, batch weights, and project specific or historical laboratory test data as required. The compressive strength of the concrete cylinders tested and/or reported as part of the mix design submittal must meet the verification strength requirements.

Four methods of verification of proposed concrete mix designs are acceptable.

- 1. **Method 1 - Same Mix Design.** Verification based on past experience with the same mix design and the same materials. Supporting documentation shall include, for a minimum of three independent samples, the test results of temperature, slump, air content, compressive strength, and age of concrete at the time of strength testing. Each compressive strength test shall consist of the average of two cylinders. There shall be no substitutions of materials under Method 1, including admixtures or fly ash, or changes in mix proportions.

2. **Method 2 - Similar Mix Design.** Verification based on past experience with a mix design similar to the proposed mix design that used aggregate materials similar to those to be used on this project. Material substitution in the established mix design shall be restricted to changes of aggregate sources. Coarse aggregate sources may be substituted provided the new source is of the same type (i.e. natural gravel, quarried stone, slag) as the original aggregate. Substitution of fine aggregate sources will be permitted. No other material substitutions, including fly ash type or admixtures may be made.

Required supporting laboratory test documentation is the same as for Method 1. All material properties for the substituted aggregate materials must be included. Calculations must be submitted showing how the mix proportions were adjusted, based on the documented differences in specific gravity and absorption of the substituted fine and coarse aggregates, to produce a theoretical yield of 100 percent.

3. **Method 3 - Trial Batches.** Trial batches shall be based on the same materials and proportions proposed for use on the project. Trial batches should be prepared at least 40 calendar days prior to the start of concrete placement in order to allow 10 days for review. The mix design laboratory test data must include the temperature, slump and air content of the concrete; the compressive strength of at least two cylinders molded and tested at the same time; and the age of the concrete at the time of strength testing.
4. **Method 4 - Annual Verification.** At the Department's option, verification may be on an annual basis for a concrete plant rather than on a project basis provided the sources and proportions of the constituent materials, including fly ash and admixtures, do not change. If this project is the continuation of work in progress during the previous construction season and written certification is submitted to the Engineer that materials from the same source and with the same mix design properties are to be used, the Engineer may waive the requirement for verification of mix designs.

Table 605- 1 Minimum Mix Design Requirements for Concrete QA

Mix Design Parameter	Grade of Concrete				
	D (a)	S1	T	S2/P1	S3/P2
Class Design Strength (28 days, psi)	4500	4000	3500	3500	3000
Verification Strength (b) (28 days, psi)	5000	4500	4500	4000	3500
Maximum Water/Cement Ratio (lb/lb)	0.44	0.50	0.50	0.50	0.50
Minimum Cementitious Material Content (lb/yd ³)	520-660	520-612	520-612(c)	520-612(c)	500-565(c)
a. Water reducing or water reducing retarding admixtures shall be used. b. Or 90 percent of class design strength at 7 days. c. Cementitious material may be reduced by five percent if a water reducing or water reducing retarding admixture is used.					

- C. **Mix Designs Using Fly Ash.** If fly ash is added to concrete, the restrictions cited in subsection 601.03.G.3 regarding the maximum weight and the maximum substitution ratio do not apply. If the Contractor elects to use concrete containing a separate addition of fly ash, the Contractor shall provide a concrete mix design as described herein, except that fly ash shall not be greater than 30 percent of the cementitious material. The combined weight of fly ash and cement shall be used to determine compliance with the water-cement ratio and minimum cementitious material requirements listed in Table 605-1.
- D. **Laboratory Requirements.** Laboratories, including field laboratories, used for producing mix designs or for quality control and quality assurance testing of concrete materials must demonstrate that they are equipped, staffed, and managed so as to be capable of batching, and testing Portland cement concrete in accordance with the applicable ASTM test methods. Mix designs submitted under Method 3 (trial batches) must include a statement, signed by a certified concrete technician (Michigan Level II), that all applicable ACI and ASTM methods have been followed in verifying the mix design.
- E. **Changes in Materials and Proportions.** The Engineer shall be notified prior to any change from one approved mix design to another for the same grade of concrete. Minor adjustments in the material proportions of an approved mix design will be permitted in accordance with subsection 601.03.G.2. Any change in approved mix design shall be recorded in the Contractor's quality control records along with the rationale for the change.

No other changes in the source, type, or proportion of materials in approved mix designs shall be made until the requirements for documenting the specified verification strengths have been satisfied. The requirement to verify a new design as a result of a change in the source, type, or proportion of Portland cement may be waived only by the Engineer.

If written approval is received from the Engineer, concrete may be proportioned to achieve high early strength requirements by increasing the cement content in an approved mix design. This proportioning to meet high early strength requirements shall apply to small quantities (less than 20 cu yd) of concrete as may be necessary to facilitate construction progress (i.e., driveway gaps). Larger quantities of high early strength concrete, if approved, will be tested and accepted in accordance with subsection 605.03.F and associated pay items will be considered as non-critical concrete QA items.

605.03. Concrete Production. The Contractor shall provide quality control measures for the production of concrete in accordance with section 604. The Engineer will not sample or test for quality control or assist in controlling the Contractor's production operations. Continued production of concrete which does not meet specification with negative pay adjustment, in lieu of making adjustments to bring the work into conformance, will result in project shutdown until necessary adjustments are made.

- A. **Lot Size and Make Up.** Concrete shall be accepted based on the temperature, slump, air content and 28-day compressive strength of cylinders, or cores if reevaluation is necessary, representing discrete lots of material. Lot size and items of work included shall be proposed by the Contractor, and must be approved by the Engineer, prior to placement of any concrete. At the option of the Engineer, any lot may be subdivided into two or more

smaller lots. When such a subdivision is made, the specified sampling rate shall apply to each of the smaller lots.

A lot **may not include** more than one grade of concrete, concrete of the same grade having different slump or air content requirements, or concrete of the same grade having different mix designs.

At the option of the Engineer, different concrete pay items, including critical and non-critical concrete QA pay items, that use the same mix design and are placed during one or more days may be combined into one lot. Testing and analysis of the concrete in these combined lots shall apply to all of the concrete represented by the combined lot. If critical and non-critical concrete QA items are combined in a lot, testing and analysis of the entire lot shall be in accordance with the requirements for critical concrete QA items. Pay adjustments for each pay item in the lot shall be determined separately.

B. Acceptance Testing Requirements for Temperature, Slump, and Air Content.

Temperature, slump, and air content test results will be used as a basis of acceptance or rejection of the concrete. All results of temperature, slump, and air content testing shall be reported by the Contractor to the Engineer by the end of the day on which the concrete represented by those tests is placed. These test results shall be numerically sequenced with lot identification numbers and project location designation.

1. **Start Up.** The Contractor shall perform sampling and testing for temperature, slump, and air content on the first load and, if directed by the Engineer subsequent loads, for each grade of concrete delivered to the work site each day. Concrete placement shall not begin until testing verifies that the concrete meets specifications. This start up testing shall apply to each mix design including alternate mix designs for the same grade of concrete.
2. **Continuing.** During concrete placement, the Contractor shall test temperature, slump, and air content of the concrete at the rate specified in Table 605-2. These tests shall be performed on the same samples of material from which the quality assurance compressive test cylinders are molded. While these tests are being performed, discharge from the sampled truck shall be halted.

Unless prior approval has been received in accordance with subsection (C), concrete must meet the requirements in section 601 for temperature, slump and air content before compressive strength cylinders are molded by the Contractor and the material is placed into the project. If the concrete cannot be brought into specification it will be resolved in accordance with the Contractor's quality control plan for concrete. If the decision is made by the Engineer to incorporate the concrete into the project, it will be sampled and tested and all compressive strength test results will be included in the quality index analysis for the lot.

If prior approval has been given to vary the temperature, slump or air content of a mix, this must be noted on all compressive strength cylinders and test reports. Failure to note this approval may result in cylinders being rejected at the laboratory or in the requirement of further evaluation of the lot strength.

3. **Verification Tests.** The Engineer will perform a minimum of one set of temperature, slump, and air content tests, per grade of concrete daily, to provide an independent verification of the reliability of results obtained from the Contractor's acceptance sampling and testing. If results are found to deviate by more than the limits specified in the *Materials Quality Assurance Procedures Manual* under Portland cement concrete independent assurance testing, concrete placement will stop and the Engineer will immediately consult with the Contractor's quality control plan administrator to resolve the discrepancy.

- C. **Acceptance Testing Requirements for Strength.** The Contractor shall furnish a sufficient number of molds to permit making the required number of cylinders. A shortage of molds will result in the suspension of concrete placement operations. The Contractor shall sample and mold concrete cylinders; provide secure conditions for 28-day curing as required by ASTM C31; and transport the cylinders, 28 days after molding, to the laboratory to which the project quality assurance testing is assigned.

One method of identifying cylinders is to use metal identification tags which are provided by the Engineer and inserted a maximum of $\frac{3}{8}$ of an inch into the top of each freshly molded cylinder. Other methods of identifying cylinders may be approved by the Engineer. The lot identification number, temperature, air content, and slump of the concrete represented by each cylinder shall be referenced to the numbers on these metal tags or other cylinder identifier and provided to the Engineer at the end of each day on which cylinders are molded.

The Department will remove any cylinder identification tags, cap, and test the fully cured strength test cylinders for acceptance. Results of the compression strength tests will be provided to the Contractor.

1. **Sampling Frequency.** Beginning with the first truckload or batch following startup verification of temperature, slump and air content the Engineer will use the random sampling techniques described in the *Materials Quality Assurance Manual* to determine when and where samples will be taken throughout the lot for initial strength testing. The sampling rates specified in Table 605-2 will apply except that no more than one test per truckload or batch of concrete will be required. The Engineer will direct the Contractor when to take the acceptance samples, and may direct the Contractor to take additional samples for strength testing. Any additional cylinders will be tested with the regularly scheduled compression cylinders and the lot will be evaluated on the basis of the increased number of tests.

At the option of the Engineer, lots consisting of fewer than three truckloads or batches, or containing 20 cubic yards or less may be accepted without QA cylinders. QC testing is still required. If a lot is accepted without QA cylinders, 100 percent payment at the contract unit price without pay adjustment will be made to the Contractor for all concrete QA items in that lot. For lot sizes below 100 cubic yards a reduced sampling frequency is allowed as shown in Table 605-2.

2. **High Early Strength Concrete.** Except as shown on the plans, high early strength concrete shall not be used for critical concrete QA items unless written approval is

received from the Engineer. High early strength concrete used intermittently on a project as described in subsection 605.02.E shall not be included in the sampling to determine the acceptance of the lot. The Engineer reserves the right to waive or require acceptance sampling and testing of any high early strength concrete used on the project. Associated pay items will be considered as non-critical QA items for the purpose of calculating pay adjustments.

3. **Work Progress Test Specimens.** The Contractor shall be responsible for making all cylinder or beam (flexural) specimens which are required for work progress strength determinations including form removal or opening to traffic. The Contractor shall provide secure curing of these specimens in the same environment as the concrete items that they represent. These work progress test specimens shall be tested by the Contractor on the project site. This testing shall be witnessed by the Engineer.

- D. **Quality Index Analysis of Critical QA Concrete Items.** Refer to section 106 and the contract documents for additional information. Calculate the estimated percent of material which meets specifications following the procedure in section 106.

The quality index parameter for concrete is the 28-day compressive strength. The lower specification limit is the class design strength shown in Table 605-1. There is no upper specification limit for this parameter.

Note: When only a single test result is available for a lot ($n = 1$), the standard deviation is assumed to be 400 psi.

1. Further evaluation of a lot is required whenever one or more initial strength test result falls below the retest strength or when these initial strength tests indicate that the rejection limit is exceeded. If the rejection limit is exceeded the lot may be rejected depending on the results of further evaluation. If PWL is less than 90 percent it is necessary to determine if the rejection limit has been exceeded.
 - a. Substitute the retest strength shown in Table 605-1 for the class design strength and recalculate PWL using equation 106-5. This is the Retest Percent Within Limits (PWL_R).
 - b. If (PWL_R) is less than or equal to 90 percent the lot may be rejectable and further evaluation of the lot is required before the pay adjustment is calculated. Refer to subsection 605.03.E.

If (PWL_R) is greater than 90 percent, the lot is not rejectable and the pay adjustment is calculated based on the percent within limits (PWL) calculated using the class design strength - not the Retest Percent Within Limits (PWL_R).

- E. **Reevaluation of Lot Strength.** The Engineer may require further evaluation of the strength of a lot of concrete if an initial strength result falls below the retest strength or if the initial strength results show that the rejection limit has been exceeded. If the Engineer determines, based on a review of initial strength test results, quality control test results and

other project records, that further evaluation is not warranted, the pay adjustment for the lot shall be based on the initial cylinder test results.

If the Engineer determines that reevaluation of a lot using non-destructive testing or coring is necessary, this work shall be done by the Contractor at no cost to the Department. The Contractor shall propose a reevaluation plan to the Engineer for approval prior to proceeding. This plan may include coring or non-destructive testing. When non-destructive testing is approved by the Engineer the results will be used only to determine what further action is to be taken. This determination will be made by the Engineer. All reevaluation testing shall be witnessed by the Engineer.

1. Results of non-destructive testing. If non-destructive testing is conducted and no result falls below the class design strength the Engineer may elect to accept the lot at 100 percent of the contract bid price or to require that the Contractor core the lot. If one or more of the non-destructive test results indicate that the concrete in the lot is below the class design strength, the Contractor shall core the lot before the pay adjustments are determined.
 2. Concrete Coring. All coring, whether required by the Engineer or elected by the Contractor and approved by the Engineer, shall be performed at locations randomly selected by the Engineer throughout the lot. Cores must be submitted to the Department within 45 days from the concrete placement. Cores shall not be taken within 20 inches of transverse joints, within 20 inches of longitudinal joints, or within 20 inches of free edges for critical concrete QA items, 12 inch clearance in all other cases. The Department will test the cores. The Contractor shall patch all core holes full depth with a prepackaged hydraulic fast-set material selected from the Qualified Product List.
 3. When cores are taken, final disposition of the lot is based on the core results as outlined in subsection 605.03.D except that if the results of core compression strength tests indicate that the rejection limit has been exceeded the Engineer may:
 - a. Require the Contractor to remove and replace the entire lot at no cost to the Department. New initial tests shall be obtained and the evaluation procedure repeated. Or -
 - b. Allow the Contractor to leave the lot in place with an adjustment of minus fifty percent (-50%) applied to all concrete items in the lot. Or -
 - c. Allow the Contractor to submit a plan, for the Engineer's approval, for corrective action to be performed at no cost to the Department. If the plan for corrective action is not approved, either a. or b. shall be applied.
- F. **Acceptance and Payment for Non-Critical Concrete QA Items.** This section applies to all lots which are comprised of only non-critical concrete QA items. The lot is eligible for 100 percent payment at the contract unit price provided that all initial 28-day compressive strength test results equal or exceed the retest strength listed in Table 605-2 for non-critical concrete QA items. Whenever one or more initial strength test result falls below the retest

Table 605- 2 Sampling Rates, Resampling Rates and Rejection Limits for Concrete QA

	Grade of Concrete				
	D	S1	T	S2/P1	S3/P2
Critical Concrete QA Items					
Initial Sampling Rate (per lot)					
Lot size 0-100 cubic yards	3	3	3	3	3
Lot Size over 100 cubic yards	6	5	4	5	4
Retest Strength (psi)					
Lot Size 0-100 cubic yards	4500	4000	3500	3500	3000
Lot Size over 100 cubic yards	4000	3500	3000	3000	2500
Non-Critical Concrete QA Items					
Initial Sampling Rate (per lot)	3	3	3	3	3
Retest Strength (psi)	4500	4000	3500	3500	3000
All Concrete QA Items					
Rejection Limit (percent)	10	10	10	10	10
Resampling Rate (per lot)	6	6	6	6	6

strength, the lot will be subject to the re-evaluation requirements, pay adjustment and other provisions of subsections 605.03.D and E.

- G. **Combined Pay Adjustments.** When a contract unit price requires adjustment for reasons other than strength, the lot of concrete accepted based on strength requirements may have varying contract price adjustments within that lot. The total pay adjustment for the item shall be calculated using the summation of the pay adjustments involved. The original contract unit price shall be used in determining the pay adjustment for strength.
- H. **Sampling and Testing Procedures.** Sampling and testing will be performed in accordance with the methods specified in section 604.

The Contractor's personnel performing quality assurance sampling and testing shall be certified concrete technician(s) (Michigan Level I or II) through a program certified by the Michigan Concrete Association or through the Michigan Concrete Paving Association (Level I or II - three year certification). The Contractor shall furnish the name(s) and credentials of the concrete technician(s) to the Engineer prior to sampling and testing.

605.04 Measurement and Payment.

Contract Item (Pay Item)	Pay Unit
Conc Quality Assurance	Cubic Yards
Conc Quality Initiative	BAMT
Conc Quality Assurance for Freeway Shoulders	Square Yards

A. Conc Quality Assurance.

1. Payment for **Conc Quality Assurance** and **Conc Quality Assurance for Freeway Shoulders** includes all work to test fresh concrete for temperature, air content and slump; mold and cure concrete cylinders; and transport fully cured concrete cylinders to the designated laboratory for acceptance testing.
2. Failure by the Contractor to mold and cure concrete cylinders in accordance with ASTM C31 will result in non-payment of **Conc Quality Assurance** and **Conc Quality Assurance for Freeway Shoulders** for the entire lot represented by the improperly molded or cured cylinders. In addition, the Contractor may be required to core the lot at his expense to verify compressive strength. Payment for the lot will then be based on core strength test results.
3. Total quantity of **Conc Quality Assurance** and **Conc Quality Assurance for Freeway Shoulders** shall be measured and paid for based on plan quantities for all applicable concrete items included in this contract (critical and non-critical) converted to cubic yards and square yards as necessary. No payment will be made for overruns unless verified and approved in writing by the Engineer.
4. **Conc Quality Assurance for Structural Conc** will be paid according to subsection 706.04.

- D. **Conc Quality Initiative** is a budgeted amount which is established to cover the potential positive pay adjustment for critical concrete QA items as defined in subsection 605.01. Pay adjustment for each critical and non-critical concrete QA contract item is calculated using the procedure described in subsections 106 and 605.03 and the contract documents.
- E. Separate payment will not be made for the work required to provide an acceptable concrete mix design, Contractor coring, molding and testing work progress specimens, or for providing and maintaining an effective concrete quality control program. These costs shall be considered included in the applicable unit price for the concrete item.